Sn Etching With Hydrogen Plasma

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- **Introduction**
- **Sn Film Growth**
- **Hydrogen Cleaning Process**
- **Experimental Setup**
- **Results and Discussion**
- **Conclusion**

Introduction

- Sn deposition on EUV collector optics cripples reflectivity with just a couple nanometers of deposition.
- Thermal evaporation is not a solution, high energy ion sputtering is not a solution. Other methods required.
  - High temperature would result in multilayer diffusion.
  - Sputter will remove multilayers as well as the Sn.
- One possible solution is the use of hydrogen plasma to create volatile SnH_4 to remove Sn from the surface of the collector.
- The effects of pressure, flow rate, surface size on Sn *removal rates* are examined.

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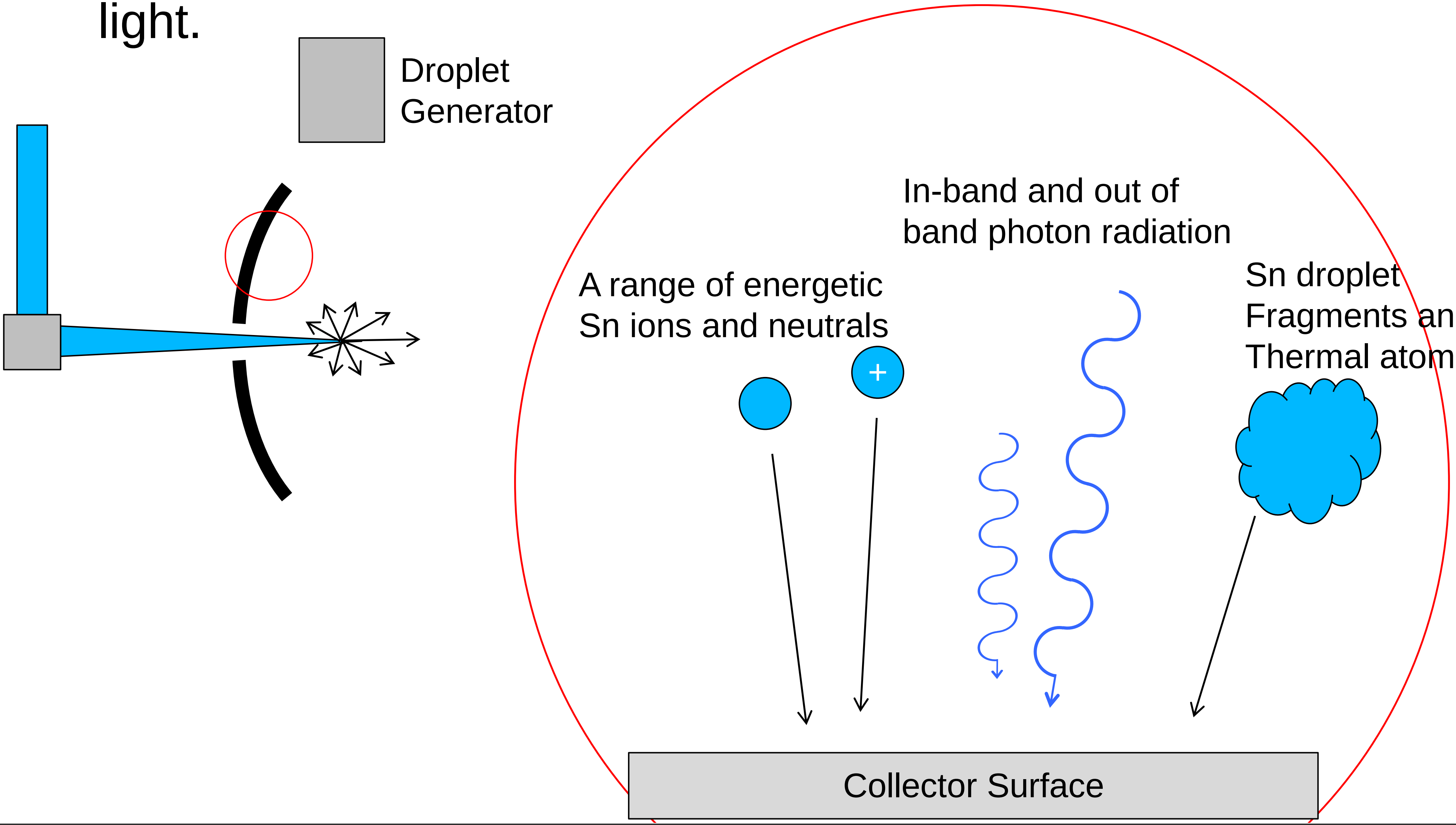
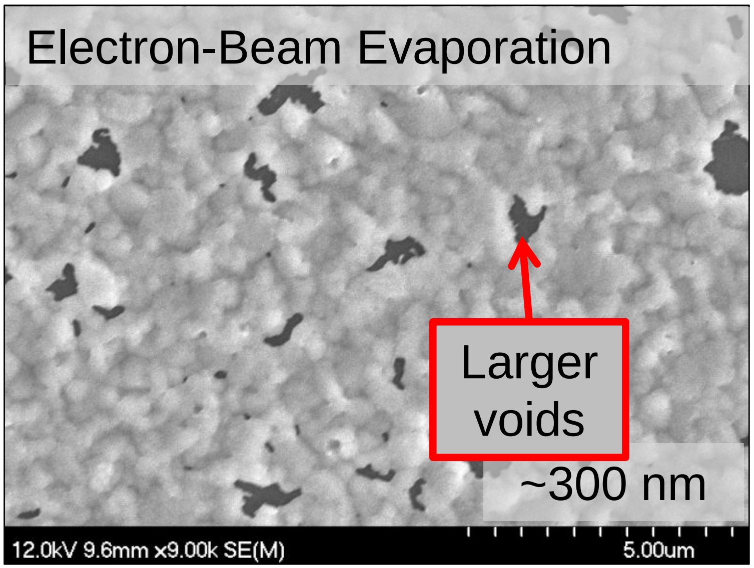
Flux Incident on Collector Optics

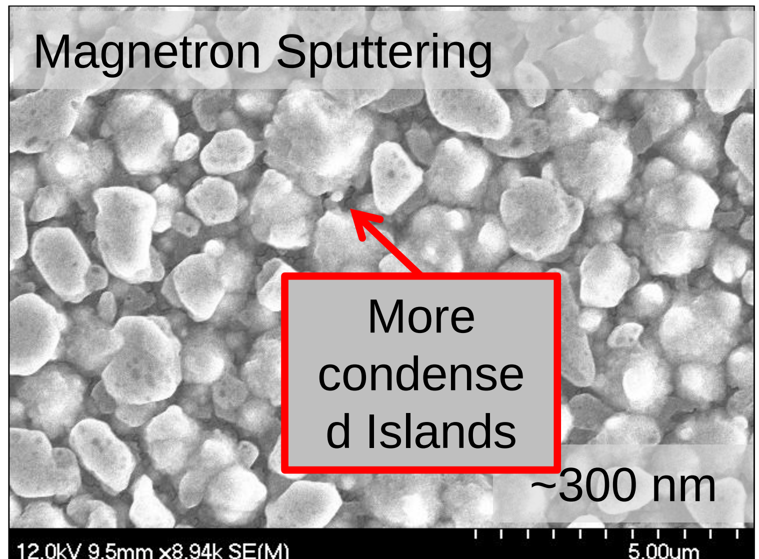
- Sn comes from the condensable fuel used in creating EUV light.



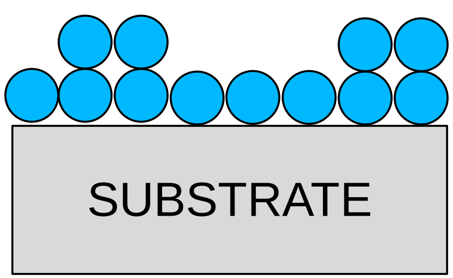
Sn Film Growth

- Sn growth depends on adatom-surface interaction.
- Sn-Si and Sn-Ru growth exhibits **Stranski-Krastanov** growth: 1-2 ML of coverage with addition island growth.

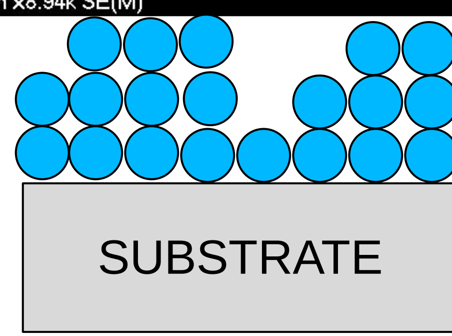




- Sn-Sn:Sn-Si ➔ 1.35
- 19.5% mismatch resides slightly within SK growth[1]
- Variations in deposition parameters can affect how Sn is grown.



Thermal Deposition
T < 0.1 eV

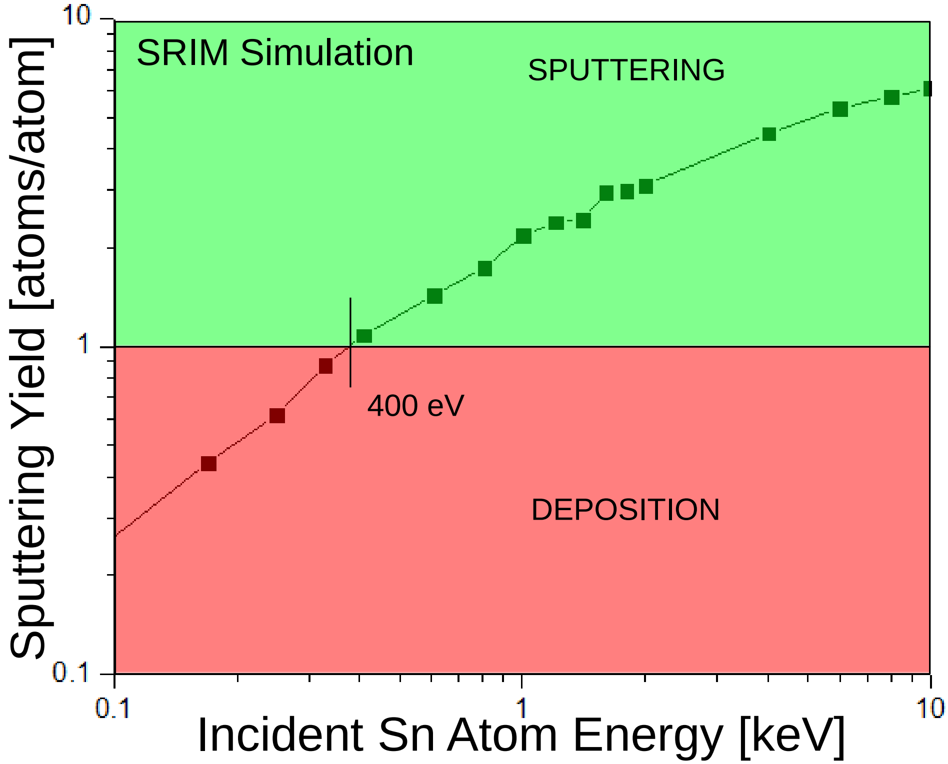


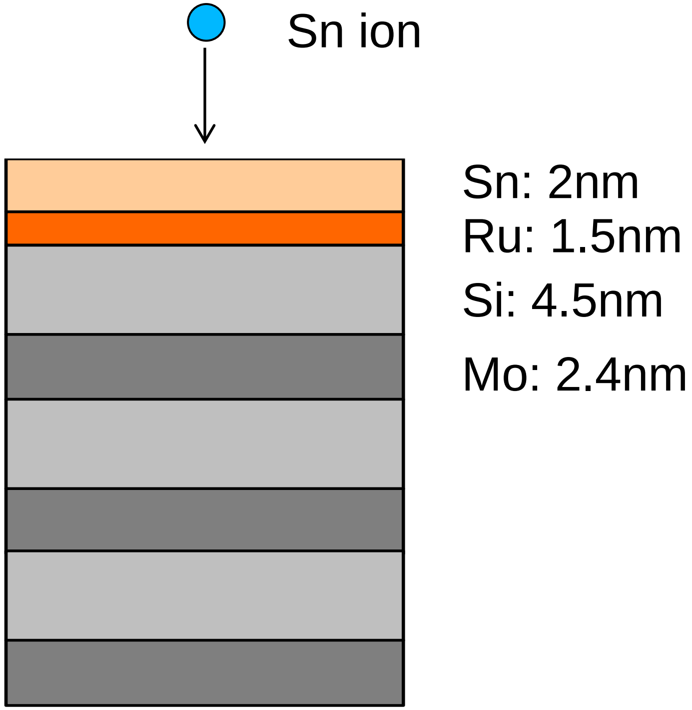
Energetic Deposition
T ~ 2-10 eV

1) Summary Abstract: Interface formation in IV--IV heterostructures: Tin on silicon M. Zinke-Allmang, H.-J. Gossmann, L. C. Feldman, and G. J. Fisanick, J. Vac. Sci. Technol. A 5, 2030 (1987), DOI:10.1116/1.574912

Deposition of Sn from EVU Plasma

- Energetic sputtering of deposited Sn by non-mitigated EUV plasma species is insufficient below 400 eV.





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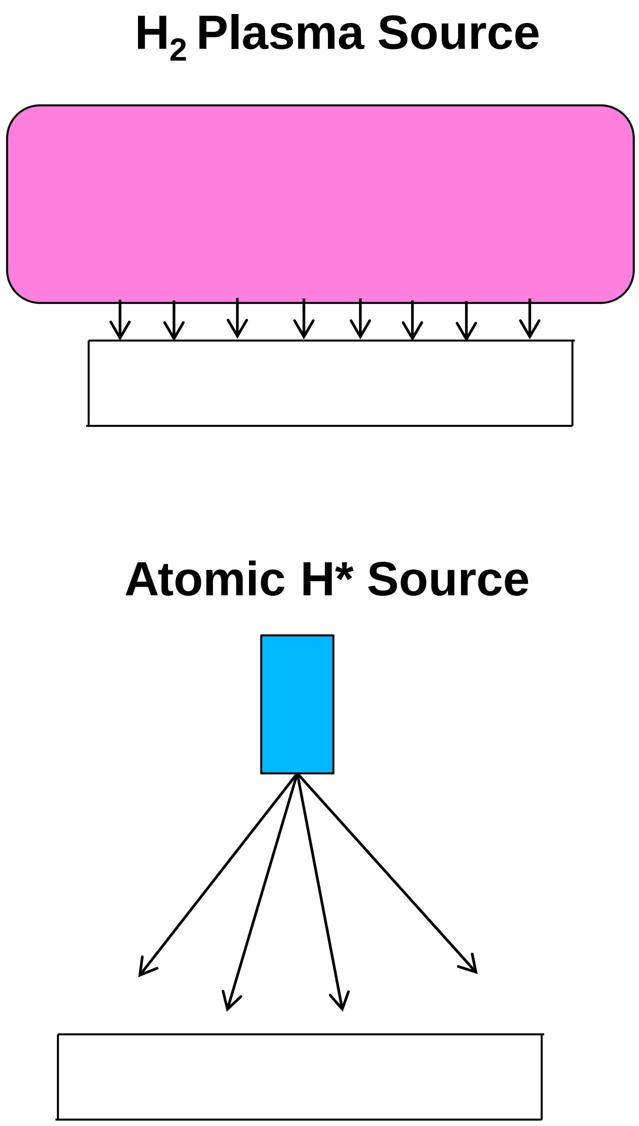
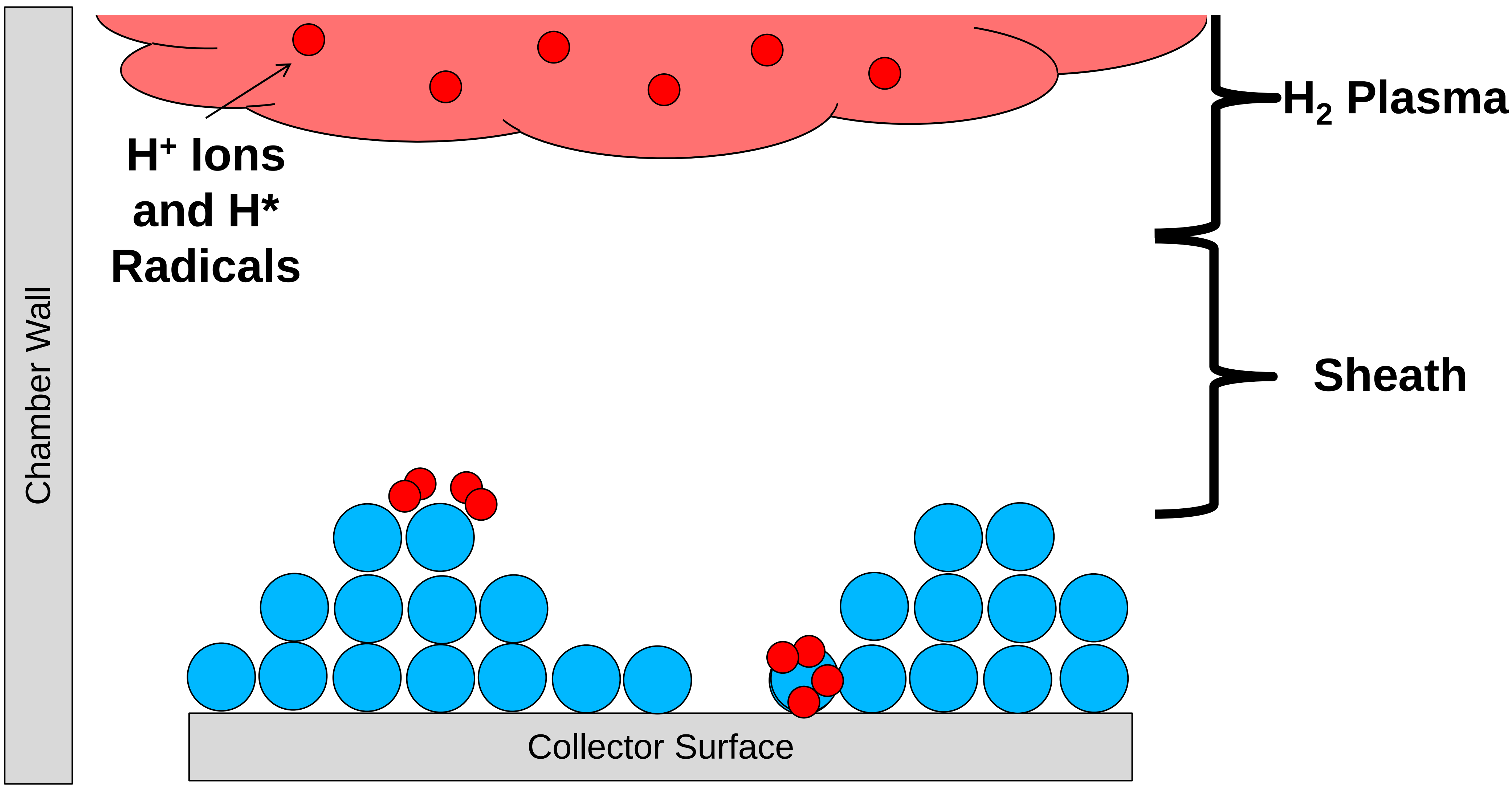
Hydrogen Plasma Vs. Atomic Hydrogen Source

- ~10x Higher Sn removal rates with H_2 plasma source versus atomic H* source in same tool configuration
- Increased uniformity
  - Plasma is a uniform radical source across the Sn removal plane
    - Located above Sn contamination
    - Radicals readily created within proximal distance of Sn contamination.
  - Atomic hydrogen sources are point sources
    - $1/r^2$ flux drop off
    - Relies on long distance diffusion



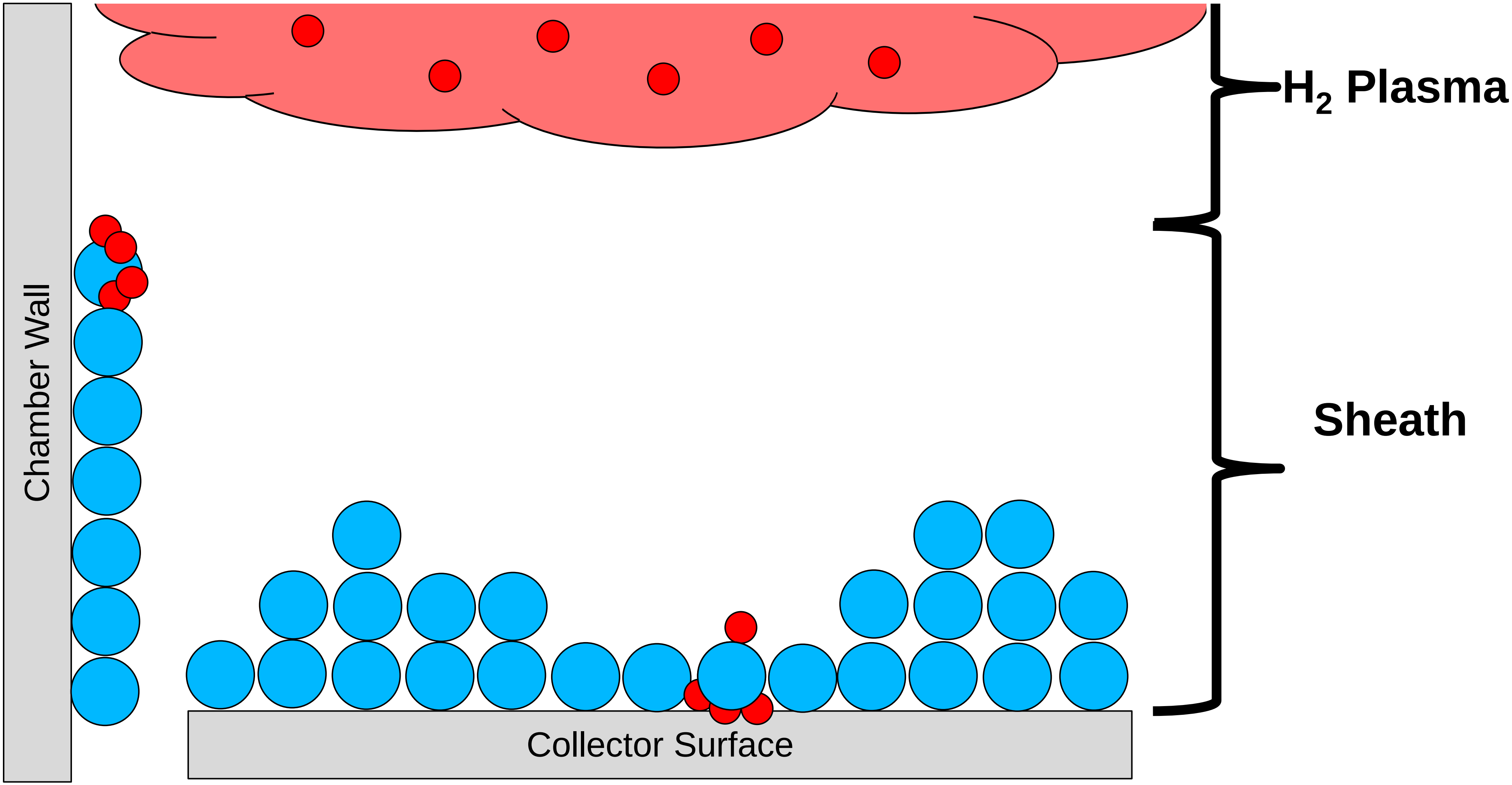
How Hydrogen Plasma Cleans

- diffuse toward the surface.



Concerns

- SnH_4 can deposit Sn on chamber surfaces.
- This Sn can be redeposited on the collector.



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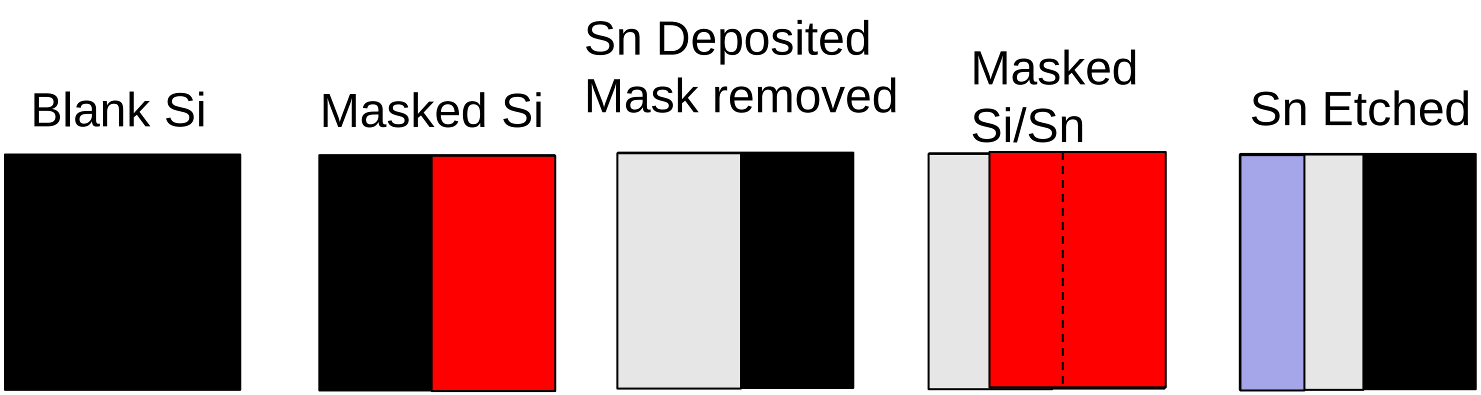
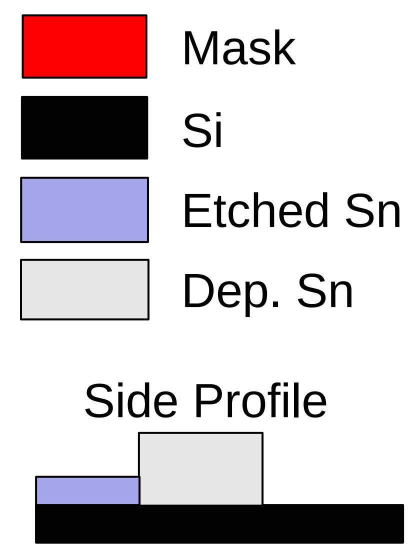
Experimental Setup

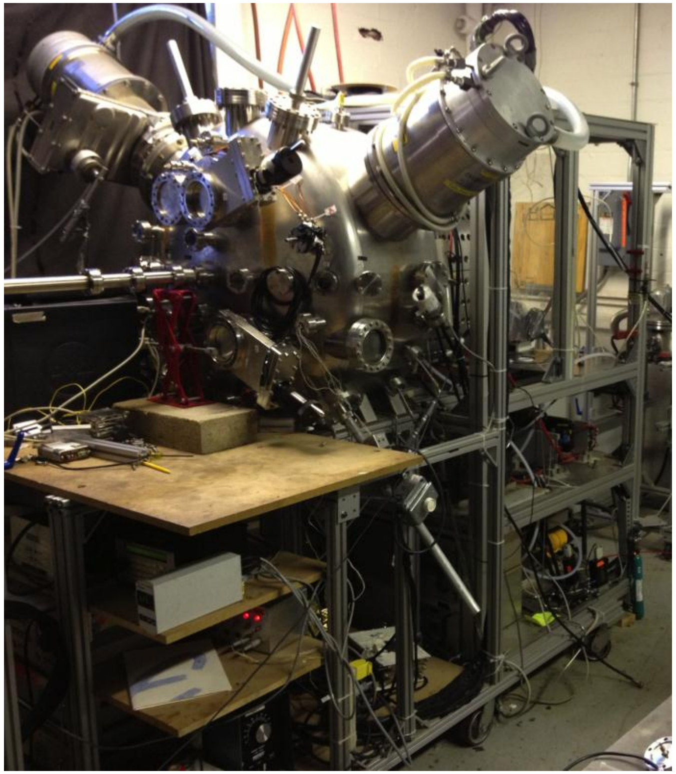
- Large stainless steel plate (16 cm wide) attached to a 13.56 MHz, 500 W max RF-generator. Samples etched 20 min.
- Pressures explored at 100 sccm for 80, 300, 500, 1000 mTorr using a gate valve to adjust pump rate.
- Flow rates of 50, 100, 500, 950 sccm explored at 80 mTorr.
- Masked, Sn coated Si witness plates located at three different locations from the center of the RF-antenna plate: 5 cm, 9 cm,13 cm

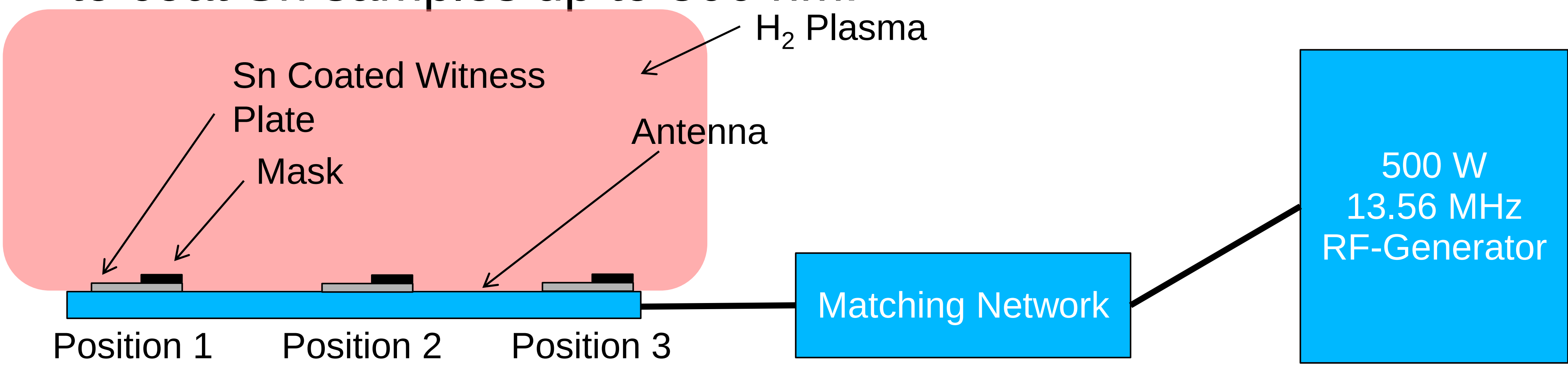




Experimental Setup

- RF-antenna installed in CPMI's XTS 13-35 source chamber to allow pressure/flow rate manipulation with adequate chamber size.
- Langmuir triple probes are utilized to measure plasma parameters at positions 1-3.
- Electron-beam evaporation utilized to coat Sn samples up to 300 nm.





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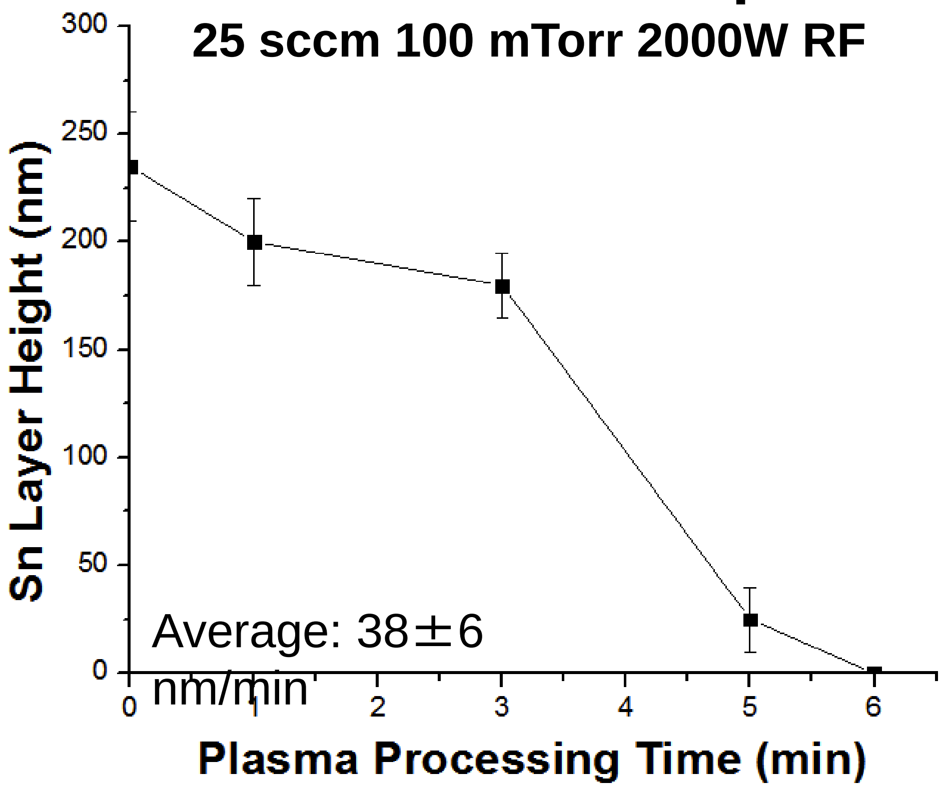
Effect of Sample Size

- Small sample etches ~ 7x faster than larger sample
- Unable to etch large sample at same conditions. Why? **Redeposition**
- Higher flow rates required to remove SnH_4 from sample.

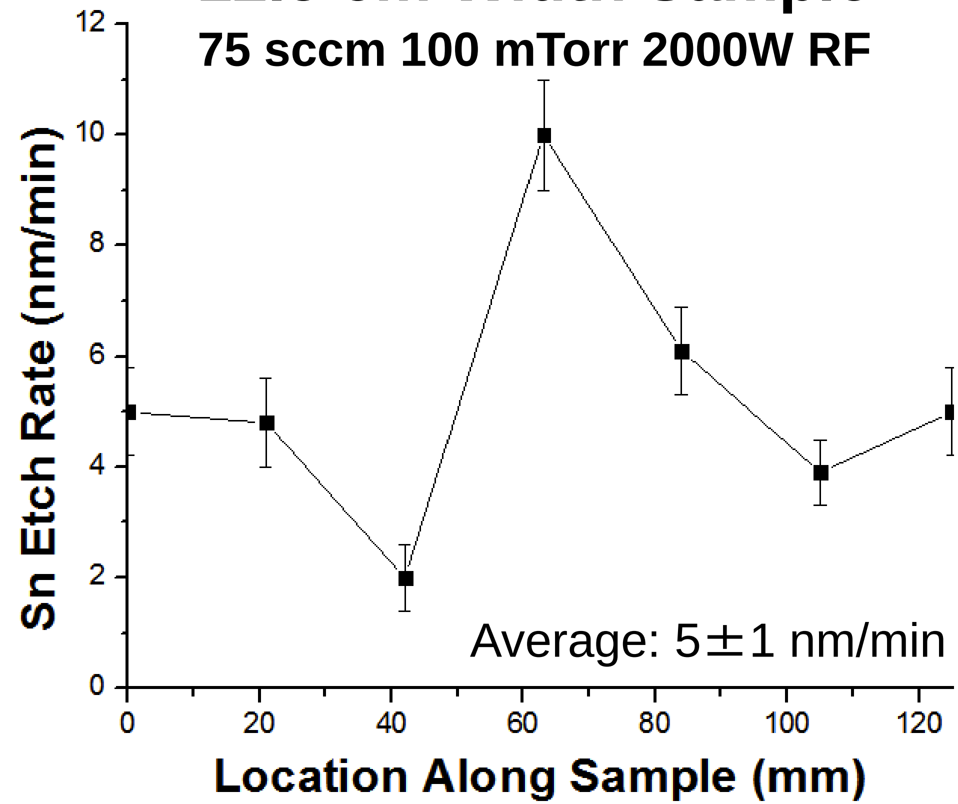
1 cm Width Sample

25 sccm 100 mTorr 2000W RF



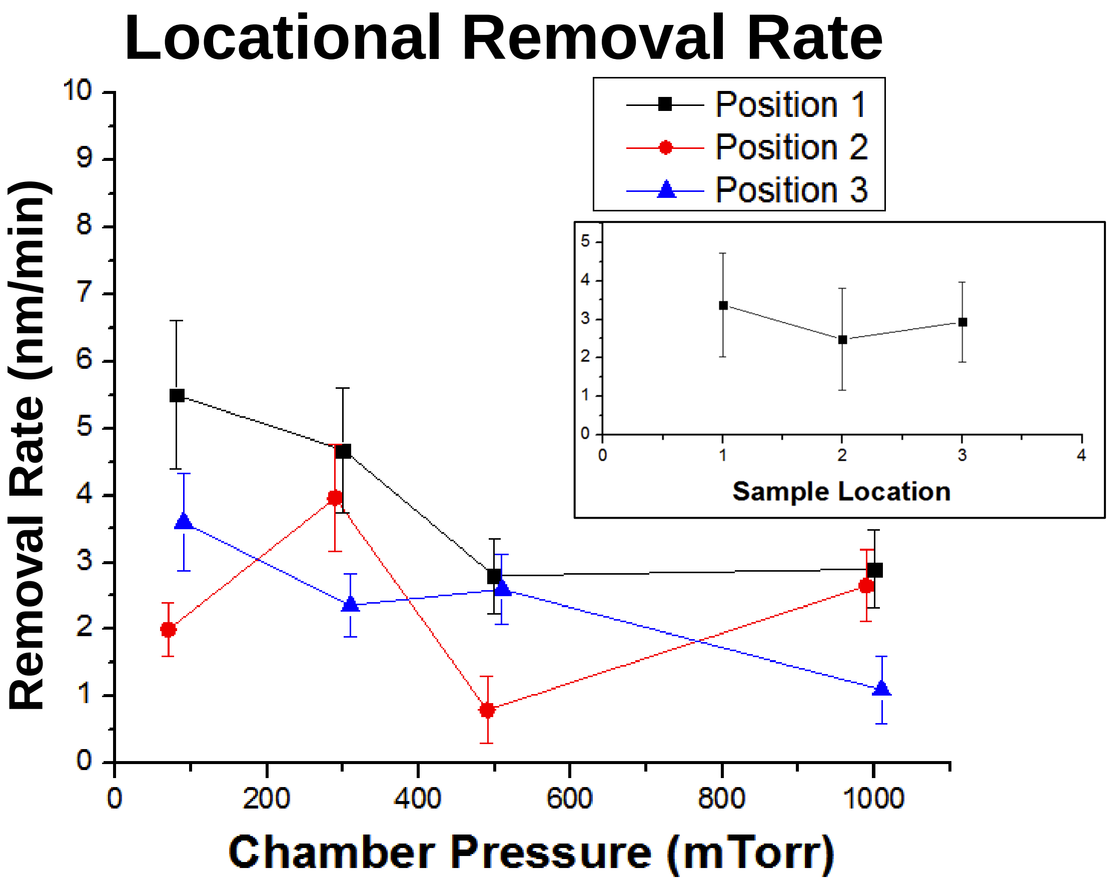
12.5 cm Width Sample

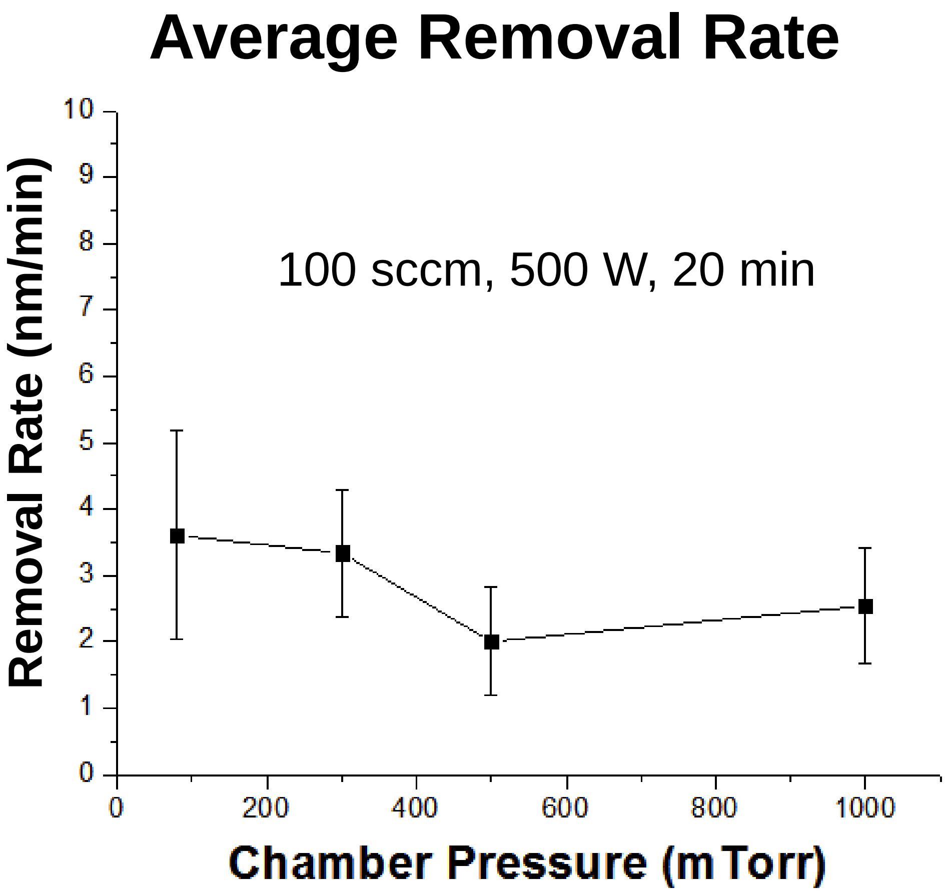
75 sccm 100 mTorr 2000W RF



Etch Rate Vs. Pressure (100 sccm)

- Etch rate maximized at lowest pressure.
- More likely to redeposit at higher pressures.
- Sample location 2 (furthest from open space) has lowest average Sn removal rate observed.

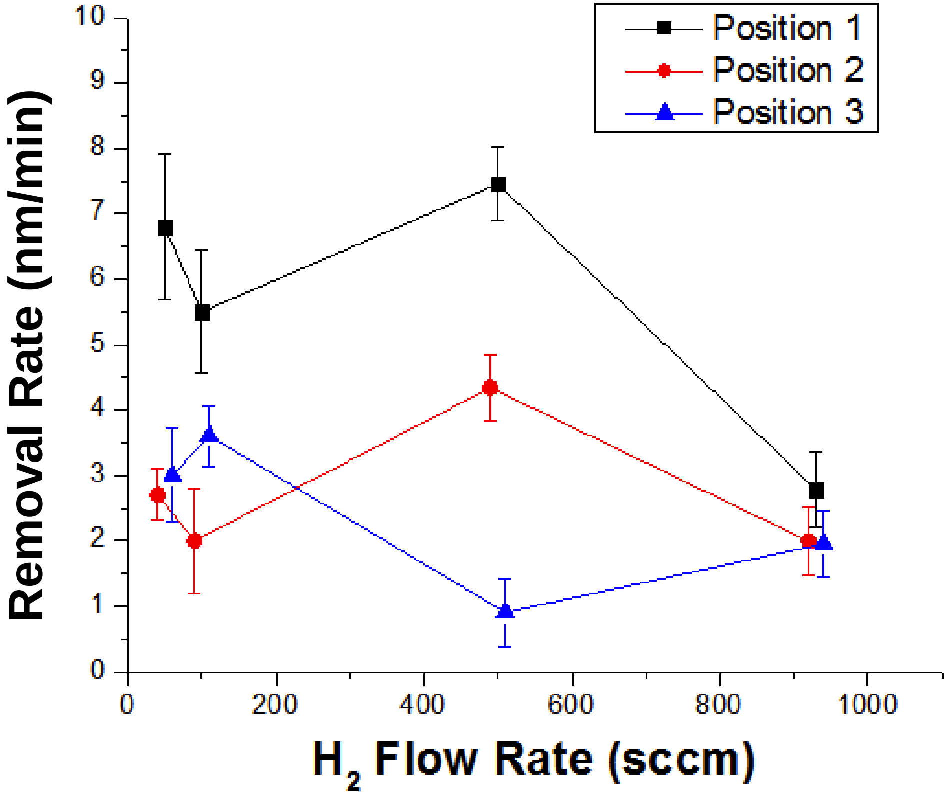




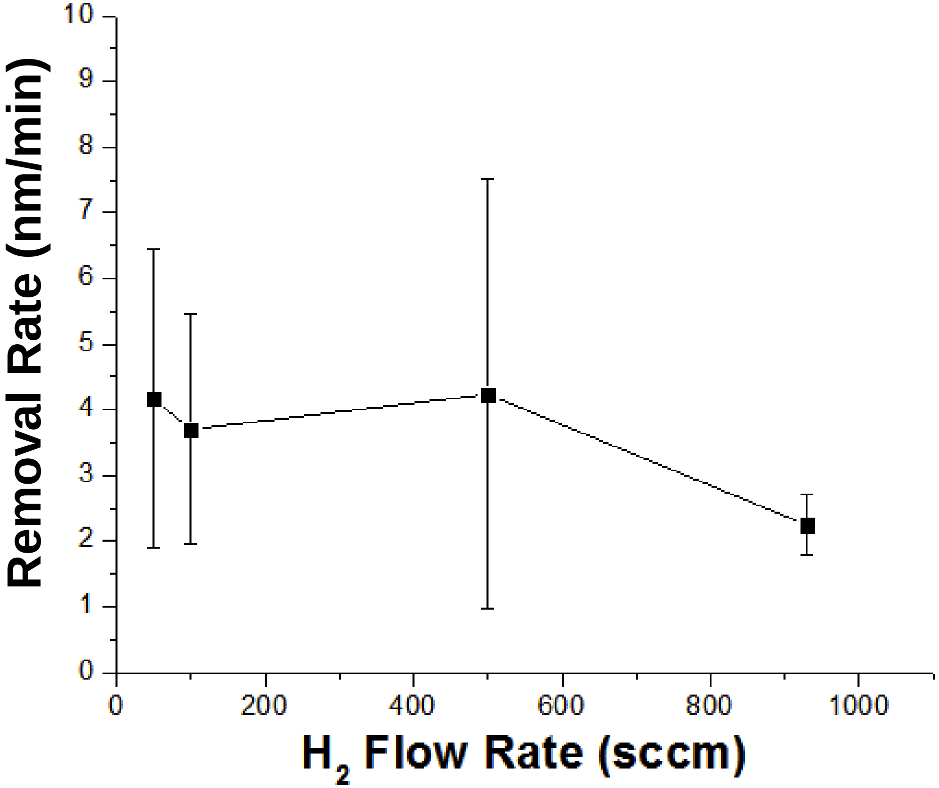
Etch Rate Vs Flow Rate

- Less than 500 sccm, too little flow rate. Above 500 sccm too few radicals.
- 950 sccm flow rate minimizes cross-antenna variation at a cost in removal rate.

Locational Removal Rate



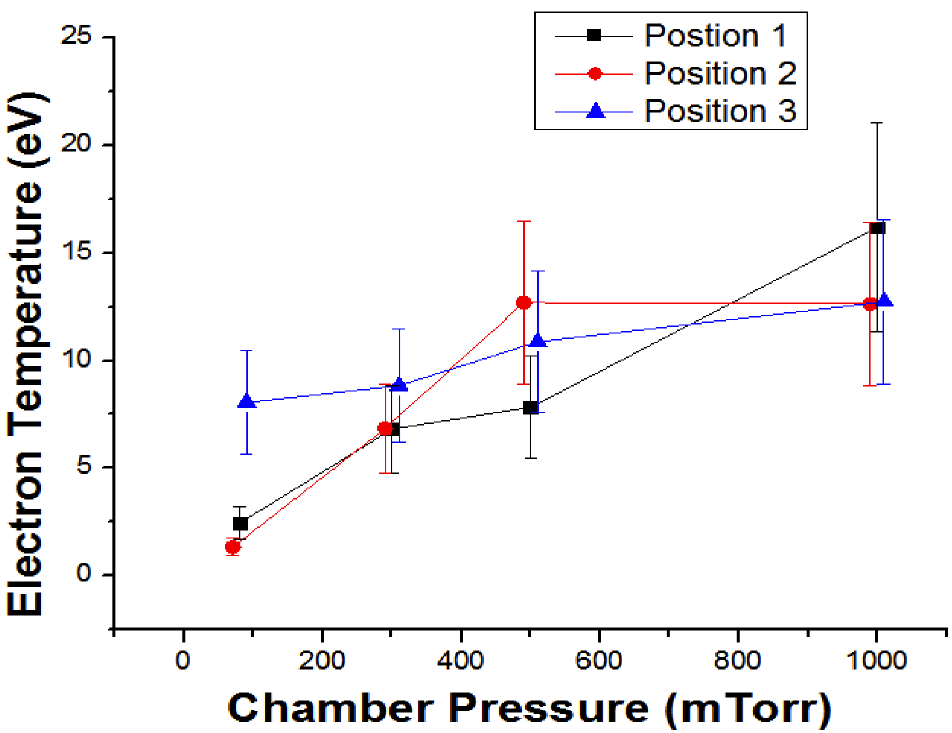
Average Removal Rate



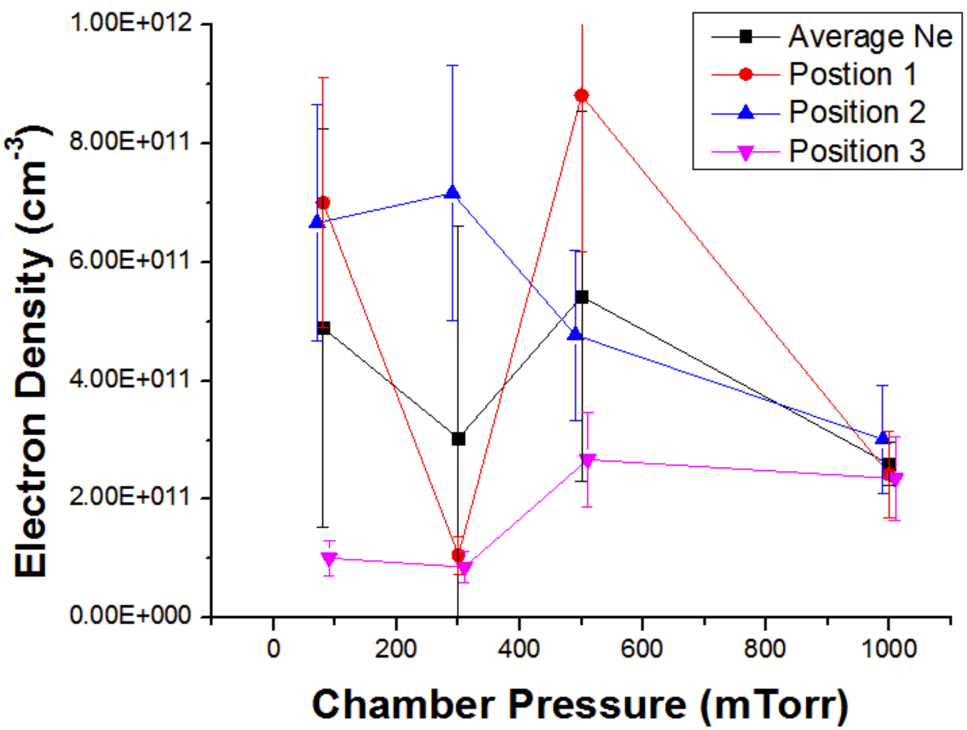
Plasma Parameters Vs. Pressure (100 sccm)

- Increasing chamber pressure results in increasing electron temperature.
- Temperatures appear high and might be the result of beams, which are not perceivable with triple probes.
- Electron density appears independent of pressure.

Electron Temperature



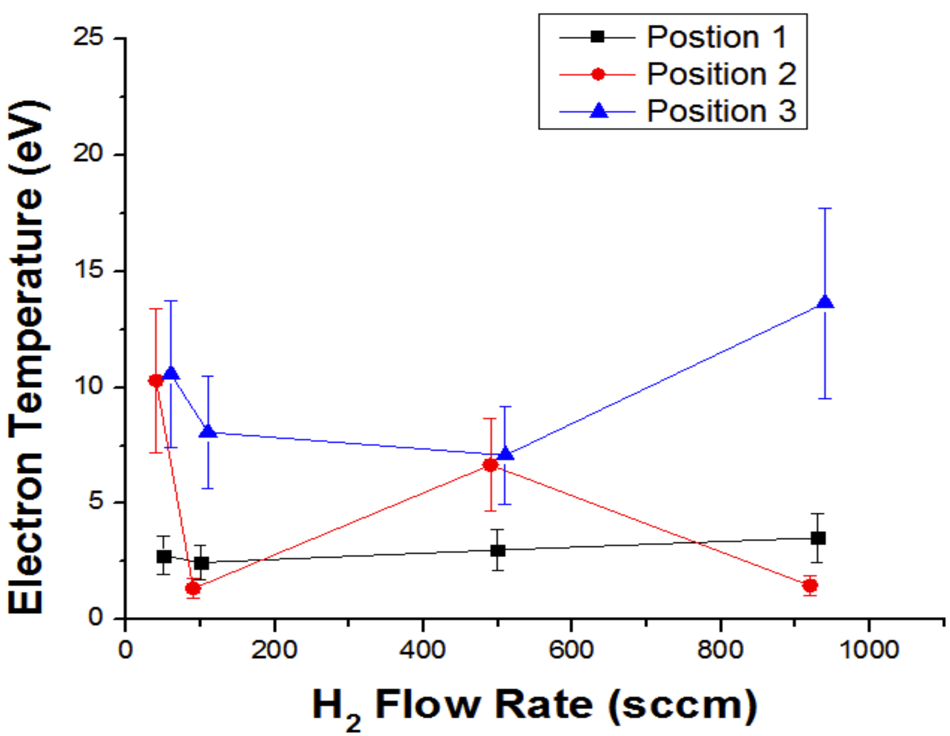
Electron Density



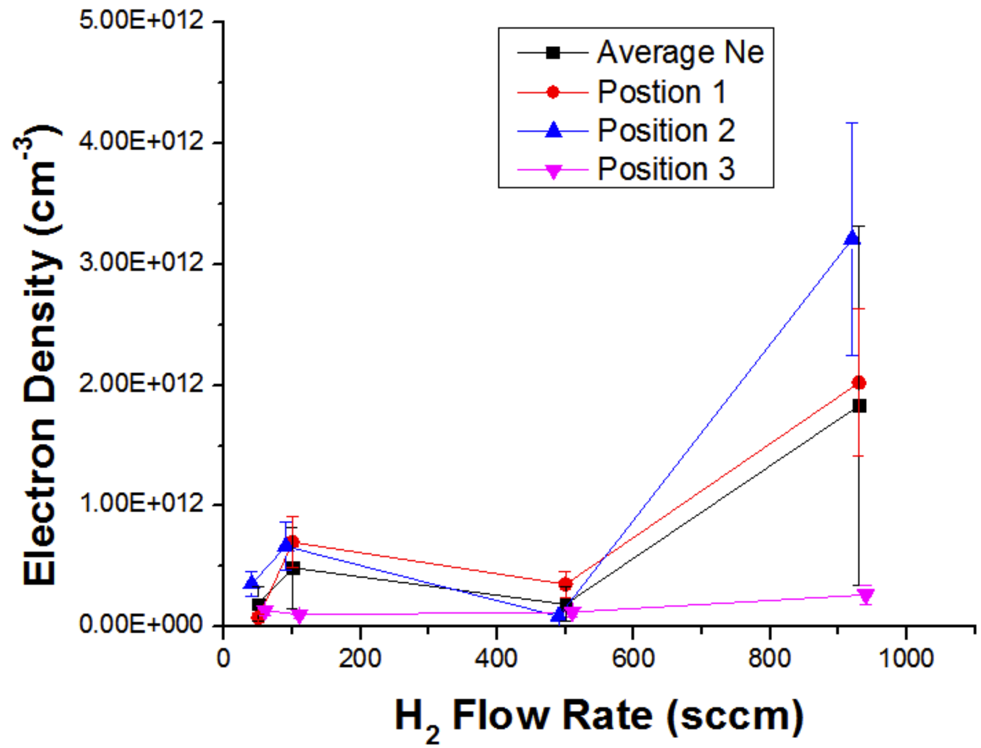
Plasma Parameters Vs. Flow Rate (80 mTorr)

- Electron temperature appears independent of chamber flow rate.
- Electron density is relatively uniform except at 950 sccm where it increases by nearly a factor of 2.

Electron Temperature

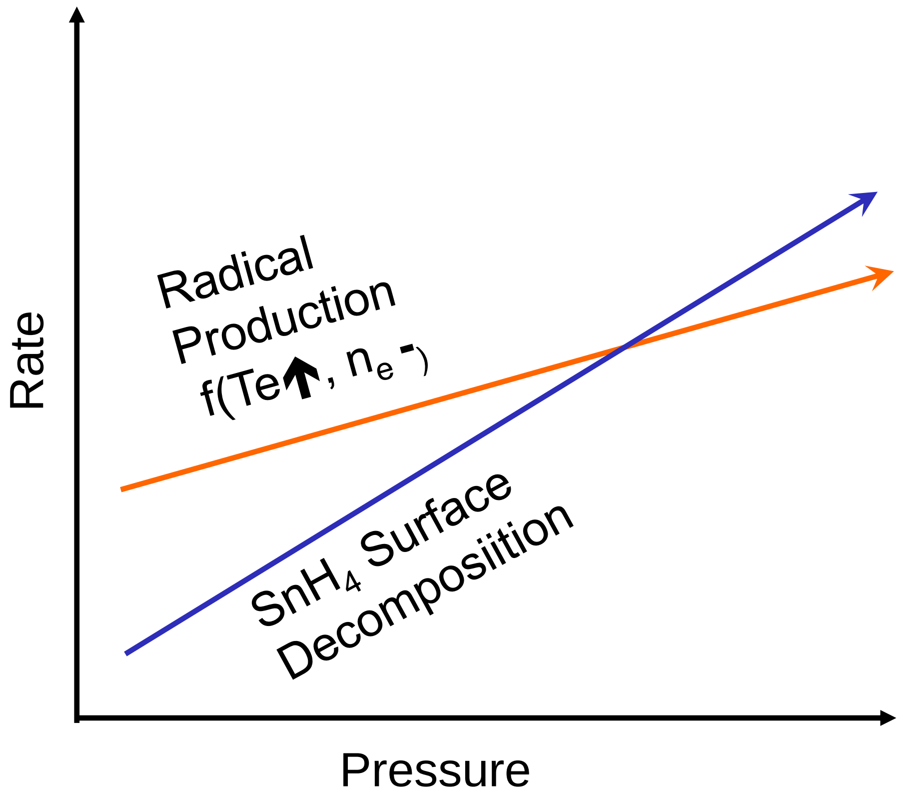


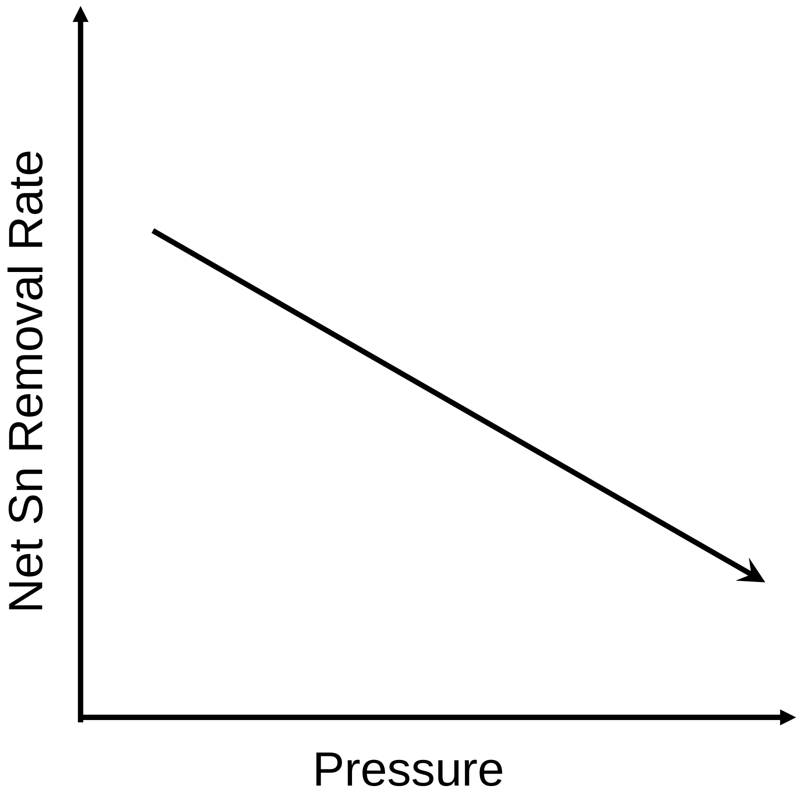
Electron Density



Recap

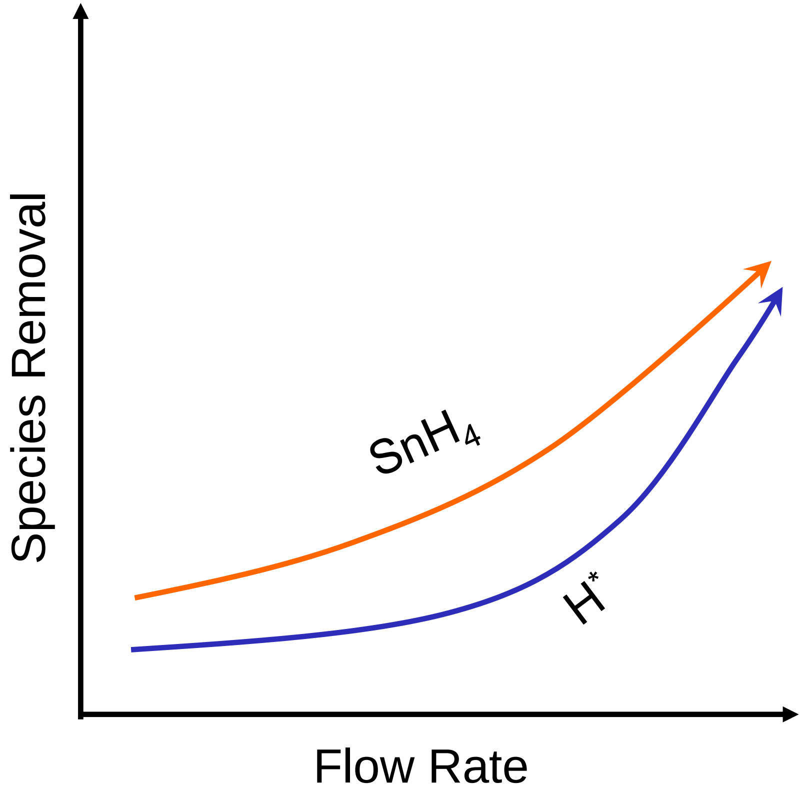
- Increased radical production at higher pressure
  - Should increase *etch rate*, but *removal rate* doesn't agree.
- Increased pressure, increases SnH_4 decomposition.

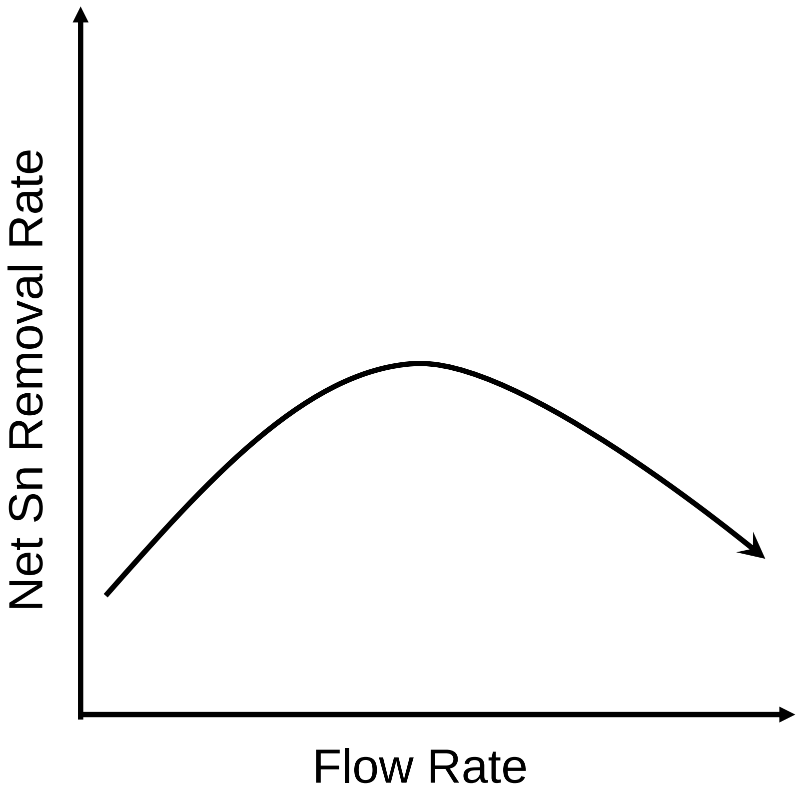




Recap

- SnH_4 removal increases with increasing flow rate
- H* not largely removed until very high flow rates





Best scenario for cleaning is low pressure and the appropriate flow rate.

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Conclusions

- It is possible to remove Sn from a collector optic using an in-situ H_2 plasma cleaning system.
- The decomposition of unstable SnH_4 makes removing Sn from large surfaces difficult but not impossible. Sn removal rate ≠ Sn etch rate.
- Higher flow rates are required to remove SnH_4 from larger samples before it decomposes.
- Under presented experimental conditions, optimal Sn removal from large surfaces occurred at 500 sccm, 100 mTorr, 500 W RF power. Net removal rates as high as 7.5 ± 0.5 nm/min.
- Net Sn removal rate less affected by variations in pressure/plasma conditions than by flow rate.

Acknowledgments

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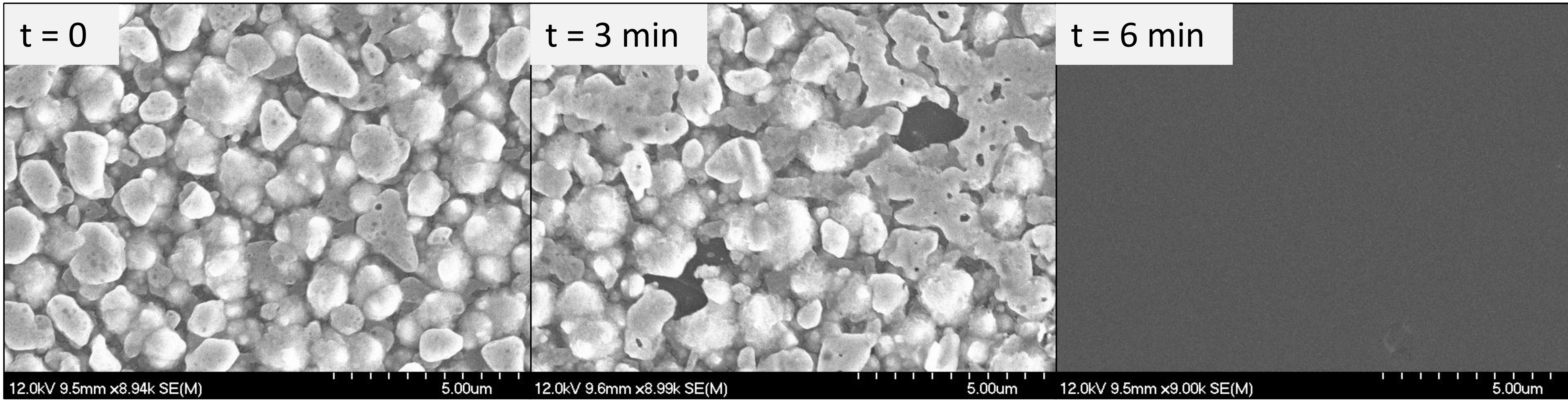
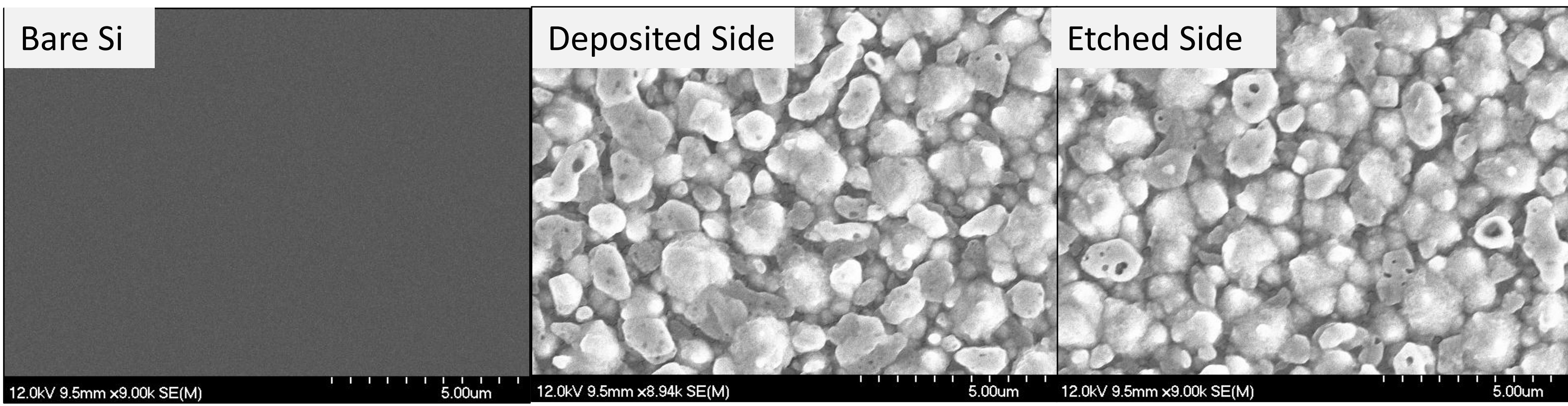
Thank You For Your Attention!

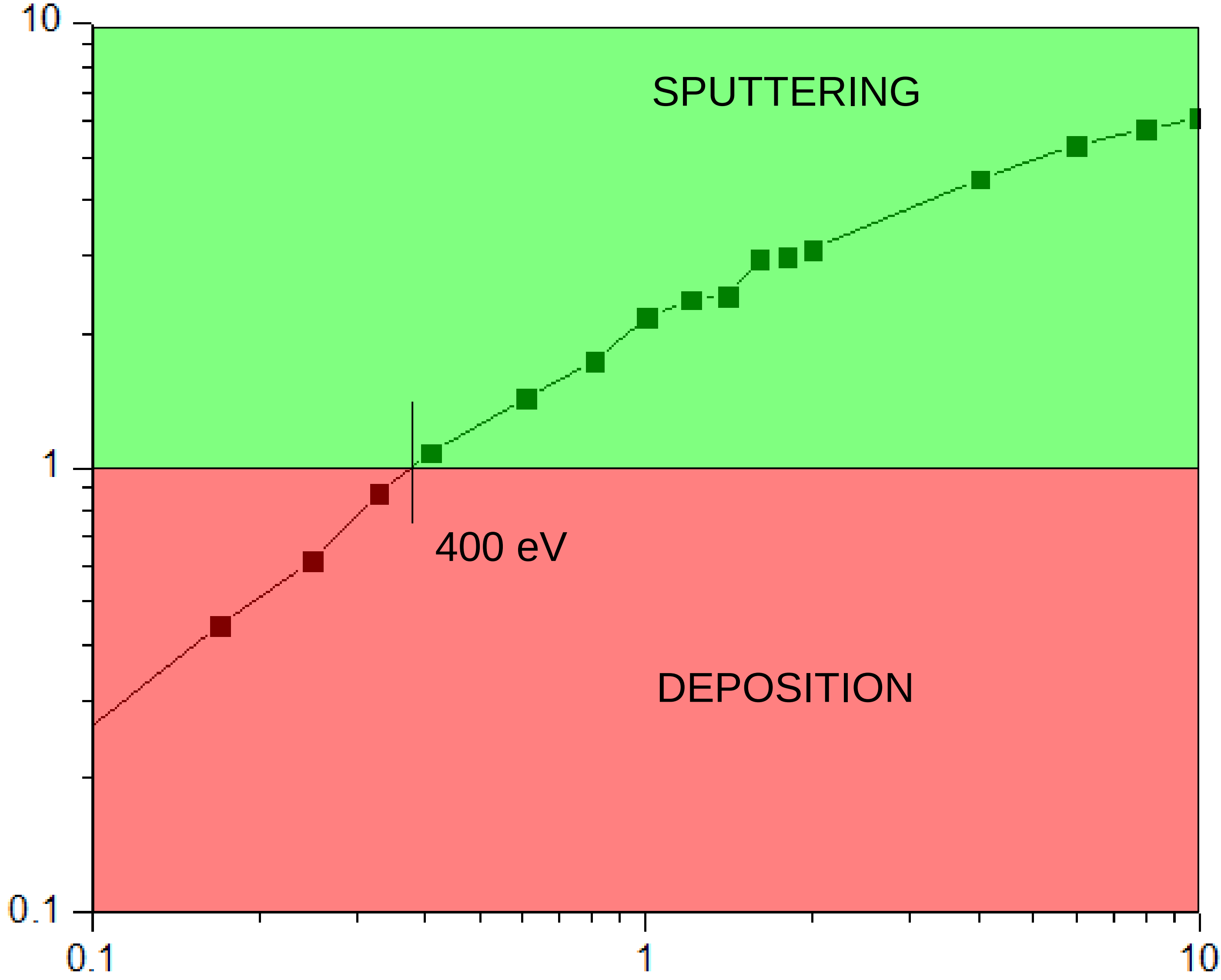
Sample Size Etch Difference

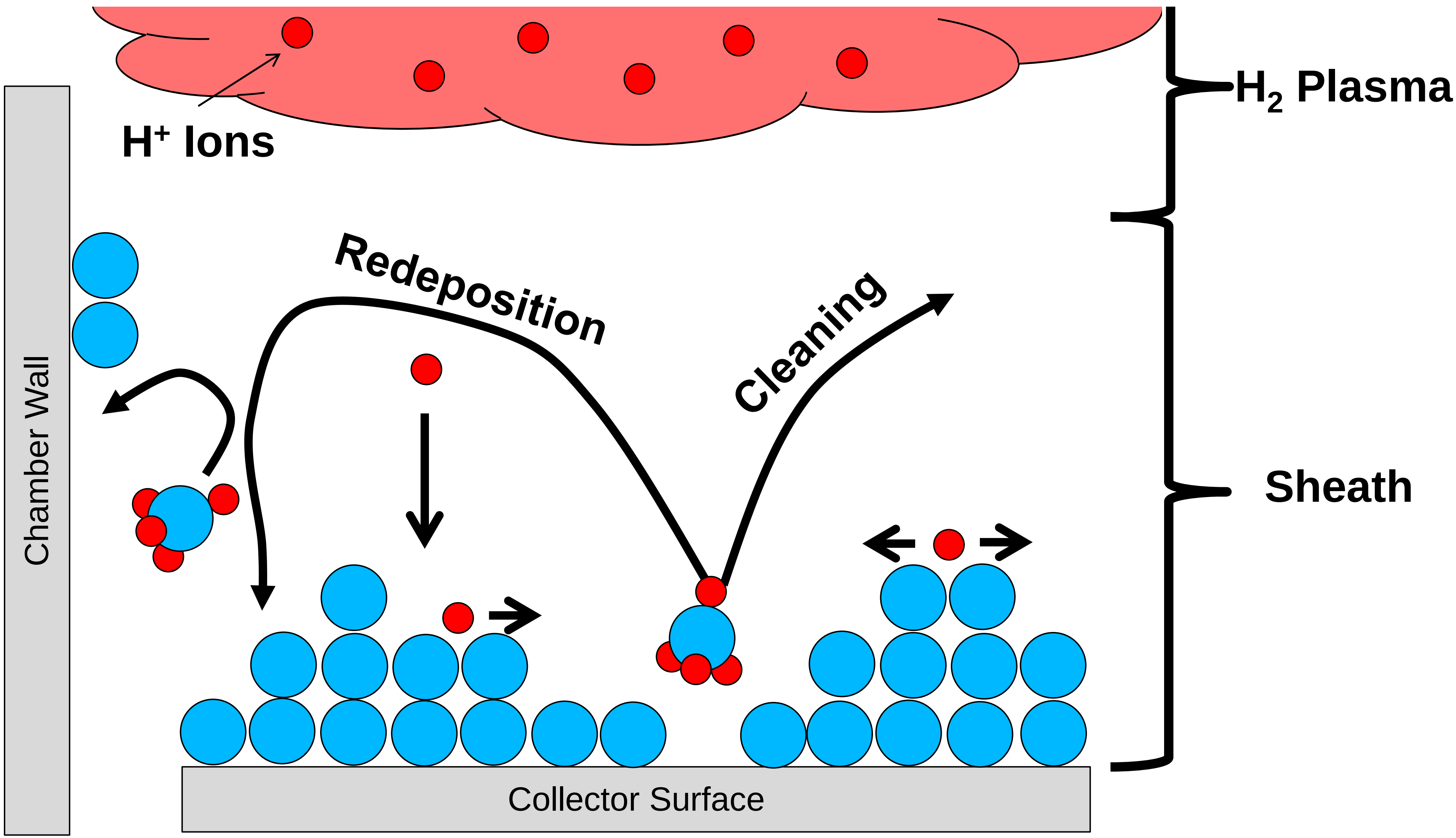
1 cm^2 Sample Size: Magnetron



125 mm Sample Size: Magnetron




10
1
0.1
SPUTTERING
400 eV
DEPOSITION
0.1
1
10


H+ Ions
H_2 Plasma
Chamber Wall
Redeposition
Cleaning
Sheath
Collector Surface